Predicting Future Sinus Augmentation Procedure using Deep Learning from CBCT scans

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Introduction

Maxillary sinus floor augmentation using the lateral window technique is a predictable procedure for implant placement in the posterior maxilla; however, Schneiderian membrane **perforation** remains the most common intraoperative complication. Previous studies[1-8] report variable risk factors and outcomes, and the role of sinus anatomical variations is not fully understood.

The **purpose** of this deep learning pilot CBCT-based study was to evaluate the association between maxillary sinus **anatomy** and membrane **perforation** during lateral window sinus augmentation.

Null Hypothesis

The null hypothesis is that no significant correlation exists between **anatomical variables** and the occurrence of sinus membrane perforation, and that **deep learning models** cannot accurately predict perforation risk using CBCT data.

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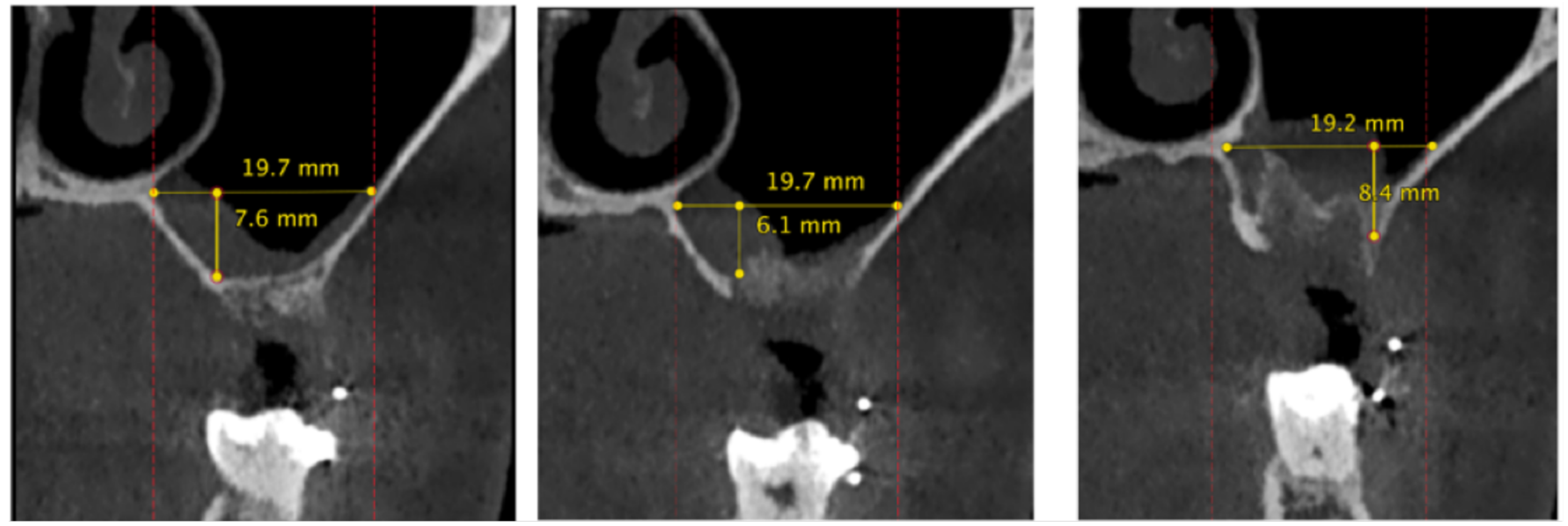
Materials and Methods

One hundred pre/post operation high-resolution CBCT scans from patients who underwent lateral window sinus augmentation between 2020 and 2024 were retrospectively analyzed.

All scans were acquired using **J. Morita** (Japan) or **NewTom** (Italy) systems, exported in DICOM format, and segmented using **3D Slicer** software to quantify sinus anatomical parameters (Fig. 1).

Schneiderian membrane perforation was determined from operative records and modeled using **univariate analysis** and **LASSO-regularized multivariable logistic regression**, with a **convolutional neural network** implemented for automated anatomical segmentation and perforation risk prediction.



Slice #1 **Slice #2** **Slice #3**

Figure 1. *CBCT images illustrating measurements of depth of alveolar bay in three representative regions mesial to distal from left to right.*

Figure 2. Workflow for CBCT-based anatomical analysis and perforation risk assessment. *Cone-beam computed tomography (CBCT) volumes were processed using trained artificial intelligence models for automated maxillary sinus and defect zone segmentation. The maxillary region of interest (ROI) was defined by excluding areas outside the defect zone, after which bone height was calculated at each axial slice within the ROI. The slice with the minimal residual bone height was selected for visualization and quantitative analysis. Segmented anatomical features and measurements were subsequently used for statistical modeling and convolutional neural network–based prediction of Schneiderian membrane perforation risk.*

Results

Two AI segmentation algorithms were initially tested on pilot CBCT datasets. Based on comparative performance, a hybrid **AI + Mathematical** approach was developed. This tool allows automatic ruler generation and measurement of residual bone height on CBCT images. **Automated** outputs demonstrated **high** agreement with **manual** measurements.

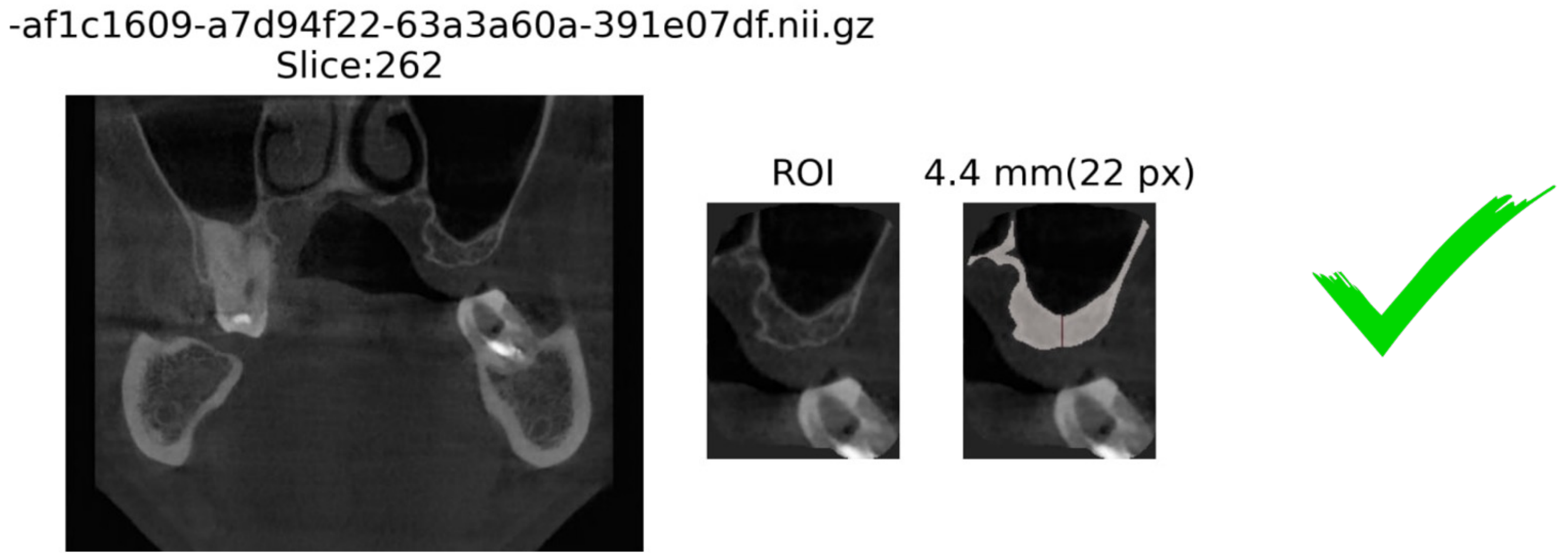


Figure 3. *Representative images illustrating algorithm-generated measurements are presented*

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Discussion

Sinus membrane **perforation** remains the most common intraoperative complication of **lateral window** sinus augmentation, with an incidence ranging from **~7-44%**.[7]

Key anatomical **risk factors** include reduced residual bone height, increased Schneiderian membrane thickness, septa, steep lateral wall angulation, and complex sinus floor morphology.

Surgical **variables** such as window size, implant timing, and clinician experience have also been shown to influence **perforation** risk. Accurate preoperative identification of these risks is critical for surgical approach **selection** and intraoperative complication prevention.

Conclusion

The integration of **AI-assisted** CBCT analysis may enhance pre-surgical risk stratification by enabling standardized, reproducible assessment of these anatomical predictors, supporting improved **treatment planning** and complication mitigation.